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JOHNSVILLE, PENNSYLVANIA

Aviation Medical Acceleration Laboratory

NADC-MA-6312 25 July 1963

Dynamic Simulation of the A4D Flash Blindness Protective System

Bureau of Naval Weapons
WepTask RAE 13J 012/2021/R005 01 01
Problem Assignment 012 AE 13-13

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SUMMARY

Operation of the A4D thermal protective system consisting of a buggy-top thermal enclosure and ELF goggles was evaluated under acceleration stresses of 1.2 to 5 G. Five experienced pilots and three non-pilot subjects operated the system within empirically predetermined limits of safety. All subjects were within the 5th to 95th percentile size range of navy pilots. Subjects in the lower third of the size range exhibited greater facility in operation of the system than those in the upper two-thirds of the size range. Recommendations are made for the location of spare ELF goggles in the A4D cockpit and preferred procedures to be followed in the operation of the thermal protective system.

RECOMMENDATIONS AND CONCLUSIONS

On the basis of the results obtained in this study, the following recommendations are made:

1. That the thermal shield be automated as early as possible.

2. That pilots using the thermal shield and ELF flash blindness protective system follow the procedures used by the subjects in this study, and

3. That pockets be placed in the A4D cockpit padding just above the consoles on each side of the seat to accommodate new and used ELF goggles.

It is concluded that under the conditions described in this report, pilots of A4D aircraft will be able to use the thermal shield - ELF flash blindness protective system and maintain safe operation of the aircraft.

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INTRODUCTION

The A4D is a high performance, lightweight attack airplane. The flashblindness protective system which has been developed for this airplane consists of the ELF goggle, and a buggy-top thermal shield which encloses the cockpit. The ELF goggle is an explosive shutter consisting of a double lens with a chamber between. Operation of a detector-trigger system explodes an opaquing carbon black colloidal suspension into the chamber between the two lenses. Once the goggle has been opaqued, the pilot must manually remove the used goggle and replace it with a new goggle. During the period between the removal of the used goggle lens and the insertion of the new one, the eyes of the pilot are without protection from environmental changes. The thermal shield which encloses the cockpit must be closed to provide the pilot with protection during this period. When the shield is closed, the pilot may remove the old goggle and fly his aircraft on instruments until the new goggle can be placed in the helmet. After a new goggle has been inserted, the thermal shield may be opened.

The thermal shield is in the process of being automated but at present it must be manually operated. Operation of the protective system requires actions by the pilot while he may be in critical phases of flight. Earlier studies have indicated that the pilot of a high performance airplane can be expected to fly his airplane safely following flash blinding for approximately 5 seconds (1). This means that a pilot must be able to close the thermal shield and remove the ELF goggle within a period of 5 seconds. He must be able to accomplish this while under the highest G stresses of which his plane is capable. In addition to the G stress, the A4D places a further restriction on the motor performance of a pilot, viz., the cockpit of the A4D aircraft is extremely small. Incorporation of the thermal shield further restricts the space in the cockpit. The purpose of this study was to determine the ability of a pilot to operate the A4D thermal protective system within limits of safety.

Apparatus

The apparatus consisted of a partial mock-up of an A4D cockpit which was installed in the gondola of the large centrifuge of the Aviation Medical Acceleration Laboratory. The instrument panel mock-up was modified to permit the inclusion of two flash lamps, located so that a subject concentrating on the instruments on the panel would be partially flash blinded by the operation of these lamps. The thermal shield was installed and a holder for new and used goggles was located on the right side of the cockpit just above the consoles. The cockpit configuration is shown in Figures 1, 2

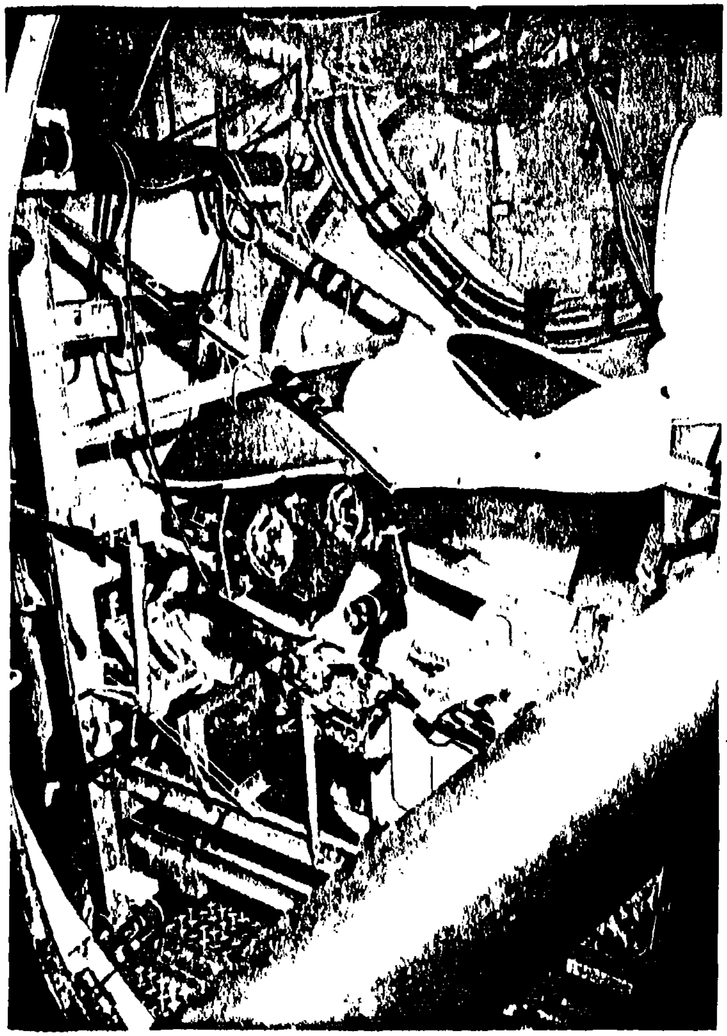

Figure 1. A4D cockpit partial mock-up showing the thermal shield and goggle holder.

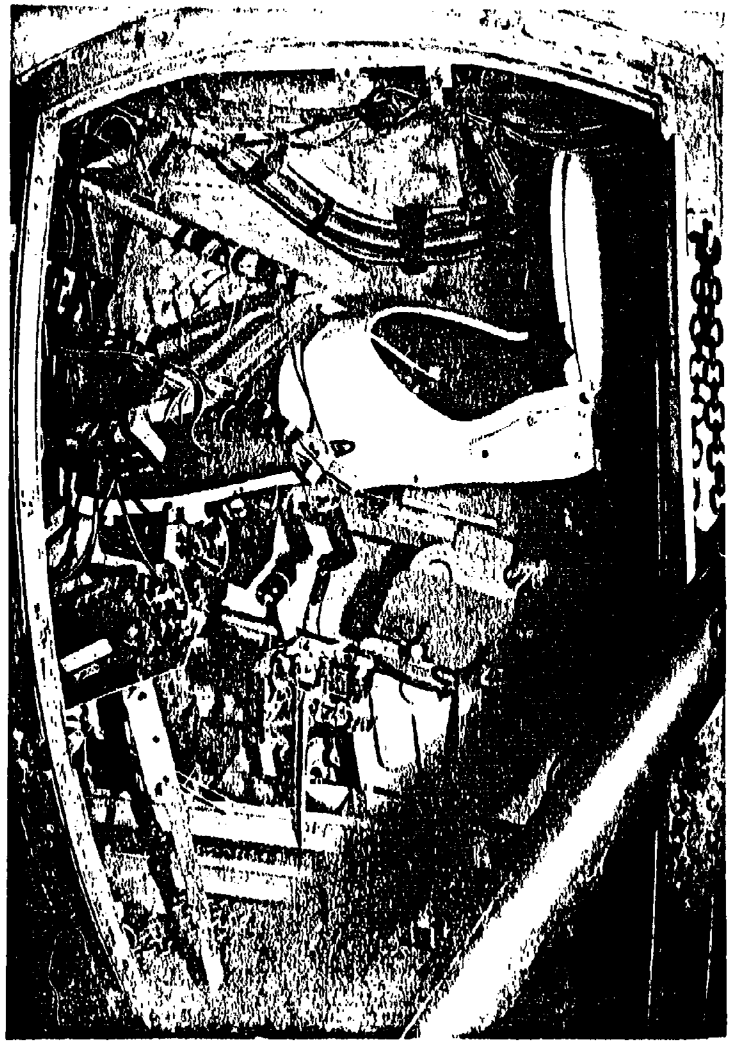

Figure 2. A4D cockpit partial mock-up installation in the human centrifuge gondola.

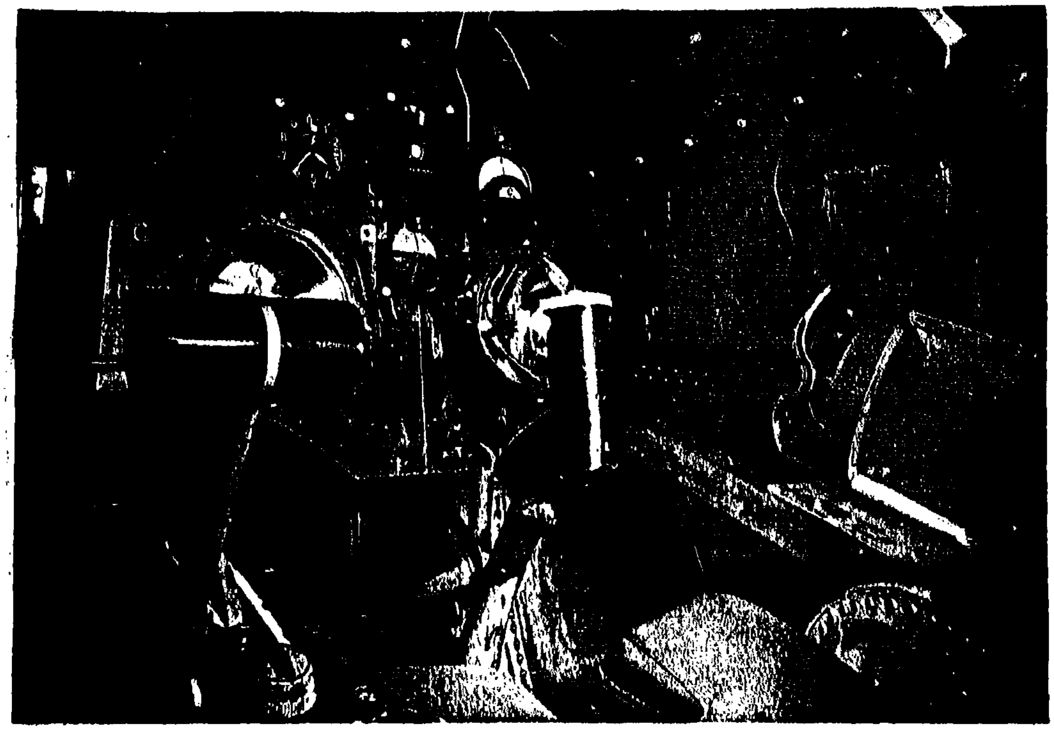

Figure 3. Modified A4D Instrument Panel mock-up and ELF goggle holder location

and 3. The helmet which accommodates the ELF goggle is shown in Figure 4. The helmet incorporates a visor which can be raised to remove the opaqued goggles from the path of vision. Once the visor has been raised, the goggle can be removed and replaced and the visor lowered again. The thermal shield, the helmet, and the goggle holder were all instrumented so that operation times could be measured. Red instrument illumination and white flood light illumination, as normally found in this aircraft, were provided. Prior to the flash blinding, only the red instrument lights were operating. At the time of the flash, all lights in the centrifuge gondola were extinguished. When the thermal shield was closed, and the visor raised, the red instrument lights and the white floodlights were turned on. After the used goggle was removed, the new goggle inserted in the helmet, the visor closed, and the thermal shield opened, the white floodlights were extinguished. Eight millimeter movie cameras were installed in the gondola so that movies of the operation of the protective system could be made.

Subjects

The subjects in this experiment were three non-pilots with extensive centrifuge experience and five A4D pilots. On the basis of anthropometric data(2), the subjects were grouped into three categories: Category I, (2 subjects) corresponds roughly with the lowest 33% of Navy pilots, Category II, (4 subjects) with the middle 33%, and Category III, (2 subjects) with the upper 33%.

Procedure

The subjects were permitted to familiarize themselves with the operation of the various parts of the apparatus. They were first given control so that by manipulation of the control stick and rudders, they were able to activate the instruments. Next, they practiced opening the visor, removing one goggle, and replacing it with another, and opening and closing the thermal shield. Under static conditions, the problem was programmed into the instruments from the computers and the subjects were required to manipulate the rudder and the control stick so that the problem which was programmed into the instruments was tracked. This practice was continued until the errors were reduced to a stable level. The subjects were then required to track under 1.2, 3, and 5 G conditions. When the errors under these conditions had been reduced to a stable level, the subjects were given preliminary trials in which the entire experimental procedure was followed.

The experimental procedure was as follows: The maneuver simulated consisted of a fifteen-second roll into a 30-second flat turn at each of five G levels, 1.2 through 5 G, and a 15-second roll out of the turn.

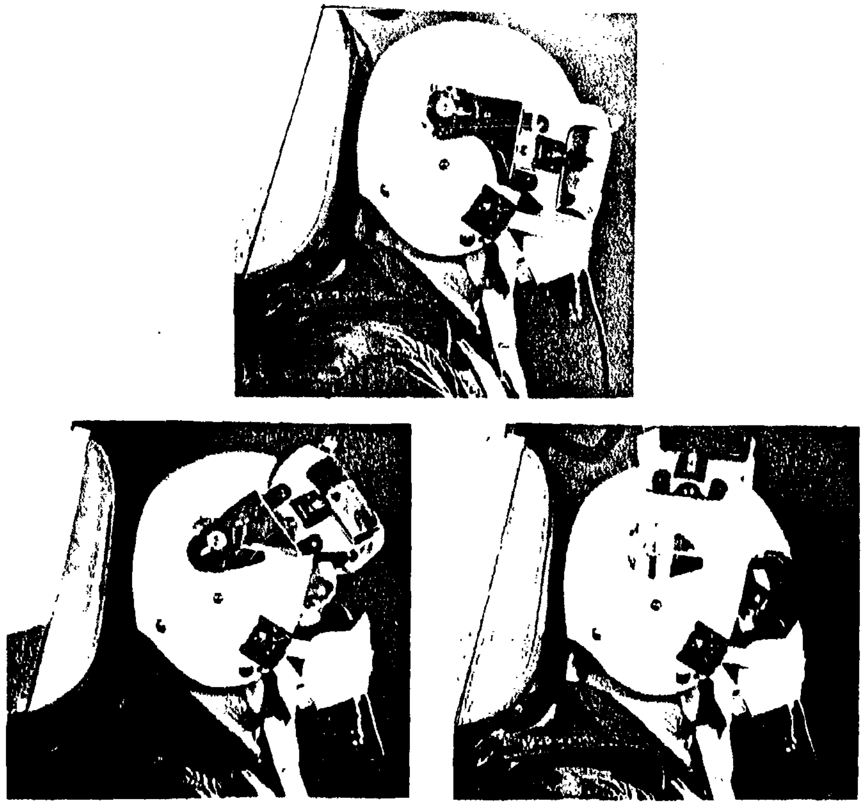

Figure 4. ELF Helmet and goggle showing visor closed and in two open positions.

The programming of the instruments included the aerodynamic characteristics of the A4D. The time required to perform this maneuver was considerably longer than in actual flight for purposes of data collection. Although the G stresses imposed on the subject were independent of his tracking performance, the tracking problem displayed on the instruments corresponded with the G stresses imposed. The tracking problem was started 15 seconds before the initiation of the G profile and continued after the G profile for a maximum of 30 seconds. At the start of each run, the subject was told the peak G for that run and the direction of turn. Following a 5-second countdown the problem was started. An auditory signal marked the start of the G profile. At a specified point during the peak G portion of the profile, the flash lamps were activated and all the lights in the gondola were extinguished. Extinction of the lights simulated operation of the ELF goggle. As rapidly as possible, the subject closed the thermal shield and then raised the visor, thus turning on the red instrument lights and the white flood lights. The subject continued to track with the thermal shield closed and the visor open. A second auditory signal marked the ramp down from peak G and the last signal, the end of the G profile. At that time, the old goggle was removed from the helmet, a new one inserted, the visor closed, and the thermal shield opened. Ten seconds later the run ended. If at any time the thermal shield was opened when the helmet visor was opened, the run was aborted, since a pilot who placed himself in this condition would be unprotected from visual damage.

When the subject was able to accomplish the required operation within these time limits, the preliminary training was ended and the experimental trials were begun. Each experimental session consisted of 10 trials, two at each of the 5 G levels. The G levels were varied according to a random schedule within each session. Records were kept of tracking errors before, during, and after flash blinding, and of the times required to close the thermal shield, raise the visor, change the goggles, lower the visor, and open the thermal shield.

Results

The 12.5, 50, and 87.5 percentile times required to manipulate various sections of the thermal protective system are shown in Table I. Closing the thermal shield and opening the helmet visor permitted the subjects to have visual access to their instruments. The median (50th percentile) time required to operate the system was 3.5 seconds or less at all G levels. The times required to change the goggle, close the visor, and open the thermal shield are greater but are also somewhat less critical, since these may be done under less stressful conditions. The median time for

Table 1

Time in Seconds Required to Operate the A4D Thermal Protective System

12.5th, 50th and 87.5th Percentile Time Scores

Task	Percentile	G-Level 1.2	2	3	4	5
Close Thermal Shield	12.5	0.8	0.8	0.8	0.8	1.2
	50	1.4	1.6	1.4	1.6	1.6
	87.5	3.4	2.4	2.8	3.0	3.2
Open Helmet Visor	12.5	0.4	0.4	0.4	0.4	0.6
	50	0.8	0.8	0.8	0.9	1.2
	87.5	1.8	1.4	1.8	2.4	6.0
Close Shield and Open Visor	12.5	1.6	1.4	1.4	1.4	2.0
	50	2.6	2.6	2.5	2.5	3.5
	87.5	4.6	4.0	4.0	4.2	7.6
Replace Goggle and Close Visor	12.5	2.4	2.4	2.0	2.4	2.0
	50	4.0	5.1	3.7	3.6	3.8
	87.5	6.6	9.0	10.8	7.2	7.2
Open Thermal Shield	12.5	1.2	1.2	1.2	1.2	1.2
	50	2.8	2.9	2.8	3.3	3.4
	87.5	8.0	7.6	10.0	6.8	6.6
Replace Goggle, Close Visor and Open Shield	12.5	4.0	4.0	4.8	4.6	4.2
	50	9.3	7.5	8.0	6.8	8.2
	87.5	14.6	12.8	18.0	16.4	13.4

this part of the task was less than 10 seconds at all of the G levels. The average errors before, during and after flash blinding are shown in Table 2 and Figure 5. In every case, the errors during flash blinding are significantly greater than the errors before flash blinding. The G_z error difference 0.95, the pitch error difference, 1.78, and the roll error difference, 2.05, are significant at the 0.01 level. It can also be seen that once the subjects have recovered visual capability, the errors are reduced in every case but two. Tables 3 and 4 show subject performance based on subject's size groupings. The average times required to manipulate the various sections of the flash blindness protective system are shortest for smaller subjects and longest for the middle size group. The average errors before and during flash blinding shown in Table 4 show no consistent variation with size.

Discussion

The results of this study indicate that the A4D Thermal Protective System consisting of the buggy-top thermal shield, and the ELF goggle can be manipulated within limits of safety under G stresses up to 5 G. The limits of safety referred to here are based on data collected at NWEF, Kirtland Air Force Base, which indicate that in the most demanding condition, pilots are able to maintain safe attitudes of their planes while blinded for up to 5 seconds (1). The assumption here, then, is that a pilot who is flash blinded or deprived of vision through the operation of his thermal protective system for less than 5 seconds will be able to maintain his plane in a safe attitude. The subjects in this experiment were without vision for less than 5 seconds, therefore, it is reasonable that they could maintain their airplanes in a safe attitude and still take advantage of the use of this thermal protective system. Although the errors increased sharply during the period in which the subjects were deprived of visual references, once they acquired the use of vision again, the tracking errors were reduced, thus indicating that they were again acquiring control of their "aircraft".

The space limitations of the A4D cockpit with the thermal protective shield enclosed are severe. While the results obtained here indicate that smaller subjects are able to manipulate the thermal protective system with greater speed than are larger subjects, the upper 2/3 of Navy pilots should still be able to operate this system within limits of safety.

The helmet which has been designed to accommodate the ELF goggles incorporates a visor which can be opened to three positions. The two forward positions present no difficulty as far as changing the ELF goggle is

Table 2

Mean Tracking Errors Before, During and After Flashblinding

	G - Level																			
Error	1.2				2				3				4				5			
	Before Flashblinding	Flashblinded	1st 5 secs. after visual recovery	2nd 5 secs. after visual recovery	Before Flashblinding	Flashblinded	1st 5 secs. after visual recovery	2nd 5 secs. after visual recovery	Before Flashblinding	Flashblinded	1st 5 secs. after visual recovery	2nd 5 secs. after visual recovery	Before Flashblinding	Flashblinded	1st 5 secs. after visual recovery	2nd 5 secs. after visual recovery	Before Flashblinding	Flashblinded	1st 5 secs. after visual recovery	2nd 5 secs. after visual recovery
G_z	0.48	0.88	0.82	0.68	0.81	1.31	1.20	1.36	1.02	2.54	1.43	1.58	1.52	2.39	2.18	1.47	1.71	2.93	2.01	2.11
Pitch	1.32	3.39	2.78	2.80	1.54	3.14	3.05	2.64	2.25	3.76	3.43	3.17	1.85	3.45	2.63	2.49	1.77	3.97	4.94	3.37
Roll	3.10	4.77	3.2	3.96	1.60	3.44	3.58	3.01	1.97	4 04	2.93	3.08	1.98	2.91	3.23	3.04	1.60	4.03	4.37	4.53

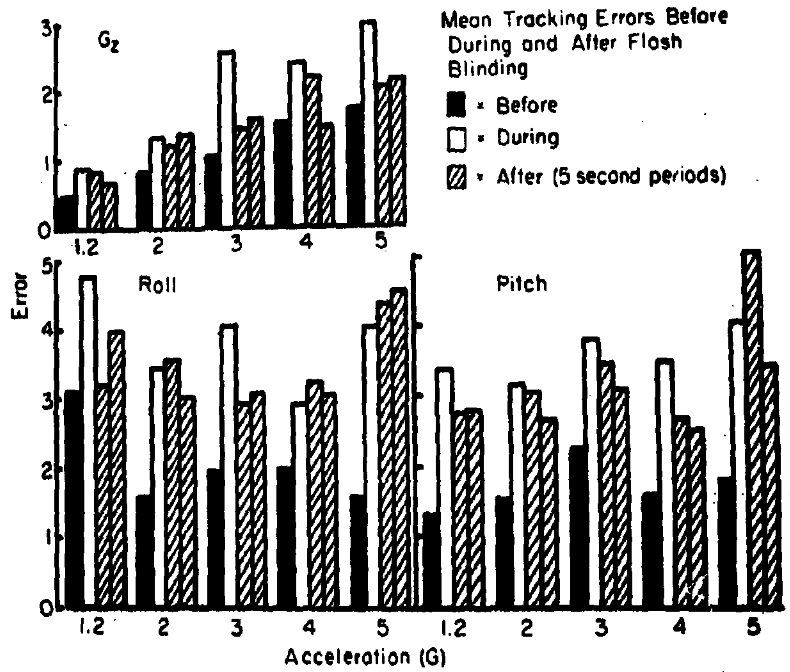

Figure 5. Median errors before, during and after flash blinding.

Table 3

Median Time in Seconds Required to Operate the A4D

Flashblindness Protective System for Three Subject-Size Categories

	Size Category *		
Task	I	II	III
Close Thermal Shield	1.3	1.8	1.65
Raise Helmet Visor	0.73	1.75	0.8
Close Shield and Raise Visor	2.13	3.5	2.3
Replace Goggle	3.63	4.23	4.6
Open Thermal Shield	2.32	5.85	2.9
Replace Goggle and Open Shield	5.95	11.05	10.1

*I = Smallest 33% of U.S. Navy Pilots

II = Middle 33% of U.S. Navy Pilots

III = Largest 33% of U.S. Navy Pilots

Coefficient of Concordance = 0.86; S = 62; $P < 0.05$

Table 4

Mean Errors Before and During Flashblinding for

Three Subject-Size Categories

Error	Size Category I	II	III
G_z			
Before	0.43	1.81	0.40
During	0.93	3.28	0.35
Pitch			
Before	2.25	1.49	1.50
During	4.96	2.79	2.95
Roll			
Before	2.54	1.78	2.33
During	4.16	3.20	5.05

concerned. The overhead position, or the completely open position, presents great difficulty in changing the visor and in manipulating the catch to close the visor when the thermal shield is closed. The subjects with the shortest sitting height had very great difficulty in manipulating the catch to close the visor when the thermal shield was closed and the visor was in the full up position, and the subjects with the tallest sitting height could not operate it at all. It was impossible for any subject to remove a goggle from the visor in this position. All subjects were able to replace the ELF goggle with one hand when the visor was in either of the other two positions. The physical arrangement in the cockpit mock-up was such that the subjects tracked or manipulated the control stick with the right hand and manipulated the goggle and visor with the left hand. The visor was raised with the left hand, and the goggle removed by depressing one of the catches while slightly dipping the head to allow the goggle to fall out of the visor. The new goggle was picked up and placed in the visor and the visor lowered again with the left hand. The location of the thermal shield release latch is such that the most convenient means of operating it is to reach with the left hand across the face, grasp the release latch which is located behind and above the right ear of the subject, and pull down the thermal shield. The thermal shield was somewhat difficult to close fully and in many instances the subjects were required to push with both hands in order to get it to close completely. Some of the subjects reported that they were able to close the thermal shield with one hand by releasing the catch with the left hand and then sliding their hand to the middle of the thermal shield and pulling it forward. Automatic operation of this portion of the protective system is strongly recommended.

In order to protect the pilot's vision, all flashblindness-thermal protective systems presently under development occlude the vision of the pilot for some limited period of time. Thus with any system direct visual contact outside the aircraft will be lost when the system is in operation. It is imperative, therefore, that visual reference to the aircraft instruments be available to the pilot as soon as possible after the thermal shield has closed. The sensing of a weapon flash and the operation of the protective system will require some limited amount of time. During this time of operation the eyes of the pilot will be exposed. If the device operates rapidly enough, permanent visual damage will be avoided and temporary visual impairment will be of such short duration that it will represent little if any danger to the pilot. The primary concern of the pilot at this time should be to acquire visual capability again as rapidly as possible without further exposure. The procedure for doing this with the thermal protective system studied here, is to close the thermal shield and remove the occluding goggle from the line of vision. The brightest illumination available should be used immediately following the occurrence of some potentially flash blinding stimulus. Ideally, the thermal

shield enclosure should close automatically and the flood lights in the cockpit should be automatically turned to full intensity. As soon as the pilot is flying on instruments, the flood lights should be reduced in intensity as rapidly as possible to regain the desired level of light or dark adaptation. Once the pilot is flying on instruments and has his plane in an attitude which can be maintained for several seconds or even minutes without difficulty, a new goggle can be placed in the helmet, the visor closed, and the thermal shield opened.

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Dynamic Simulation of the A4D Flash Blindness Protective System by Gloria T Chisum, Ph D and J H Hill, Ph D July 1963. 16 pp

1. Report NADC-MA-6312
2. WepTask RAE 13J 012/2021/R005 01 01 Problem Assignment 012 AE 13-13

Operation of the A4D thermal protective system consisting of a buggy-top thermal enclosure and ELF goggles was evaluated under acceleration stresses of 1.2 to 5 G. Five experienced pilots and three non-pilot subjects operated the system within empirically predetermined limits of safety. All subjects were within the 5th to 95th percentile size range of navy pilots. Subjects in the lower third of the size range exhibited greater facility in operation of the system than those in the upper two-thirds of the size range. Recommendations are made for the location of spare ELF goggles in the A4D cockpit and preferred procedures to be followed in the operation of the thermal protective system.

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